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Diamond Light Source Proceedings / Volume 1 / Issue MEDSI-6 / October 2011 / e34
DOI: 10.1017/S2044820110000572, Published online: 15 December 2010

Diamond Light Source Proceedings, Vol 1, e34, page 1 of 5
MEDSI-6 2010

doi:10.1017/S2044820110000572

Contributed paper

Numerical simulation and mock-up experimental measurement of the air conditioning system for the 3 GeV Taiwan Photon Source electron storage ring

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(Received 18 June 2010; revised 14 October 2010; accepted 4 November 2010)

National Synchrotron Radiation Research Center, Taiwan, is currently constructing the civil buildings and utility system of the Taiwan Photon Source. The air conditioning (AC) system of the storage ring tunnel was designed based on those of existing Taiwan Light Source and some international advanced accelerators. To predict the air temperature variation and flow pattern in tunnel more precisely, we applied 3D computational fluid dynamics scheme and built up a one-cell mock-up equipped with AC system. In the 3D numerical model, effects of magnets of the booster and the storage ring, girders, cable trays, front ends and the supplied air wind duct are all taken into account. The temperature variations and flow pattern were shown through the numerical simulation. Measured air temperature data in the one-cell mock-up were also collected.

1. Introduction

Taiwan Light Source (TLS) has been operated for more than 17 years since the first beam stored in the storage ring. In order to meet increasing demands for more state-of-the-art researches, the Taiwan Photon Source (TPS) project was proposed and designed to achieve targets of low emittance, high brightness, stability and reliability. Each subsystem of the TPS will apply the most advanced and reliable techniques to achieve this goal, so as the air conditioning (AC) system. We had applied the computational fluid dynamics (CFD) technique to simulate the TPS AC system (Chang *et al.* 2006) since the beginning of the design. To practically simulate installation and alignment of each subsystem and the AC system in the storage tunnel of TPS, we constructed a mock-up of 1/24 section of storage ring tunnel. The final design of TPS storage ring tunnel was also numerically simulated in this study.

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2. Mock-up experimental measurement

TPS is designed as a 3–3.3 GeV electron energy, 518 m circumference, low-emittance synchrotron storage ring. The booster system is designed in the same tunnel. A mock-up of 1/24 section of storage ring tunnel was constructed to simulate the installation and alignment processes, as shown in figure 1. Although there is no electrical power supplied for those subsystems in the mock-up, the air temperature outside the mock-up varied about ±1.5°C. To keep the air temperature variation stable, we set up the AC system with practical size and layout of the wind duct of the TPS, as shown in figure 1.

Figure 2 shows the air temperature history of the mock-up of 1/24 section. In the about 10 hours history, the air temperature variation of the first 2 h in the mock-up was controlled within ±0.05°C. After the transient period of first 2 h, the air temperature variation in the mock-up was controlled within about ±0.03°C.

3. Numerical simulation of the storage ring tunnel

Because the mock-up experiment does not fit the practical condition, we performed the CFD technique to simulate the air temperature distribution and air flow pattern in one section of the storage ring tunnel.

Models of the one section of the storage ring tunnel, magnets of the storage ring and booster, girders, two front ends, one cable tray, air exits and air exhausts are generated according to the actual design, as shown in figure 3.

Boundary conditions are assumed according to the designed data of each subsystem. Figure 3 also shows the simulated air vectors in the storage ring tunnel. The length of each vector in the figure is proportional to the magnitude of that vector. A virtual cross-sectional plane is generated through one air exit. Thus air velocities

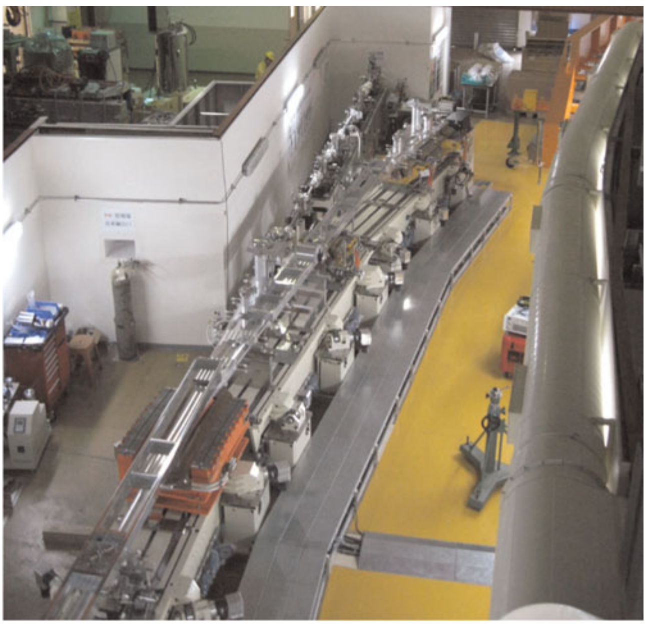

FIGURE 1. Mock-up of 1/24 section.

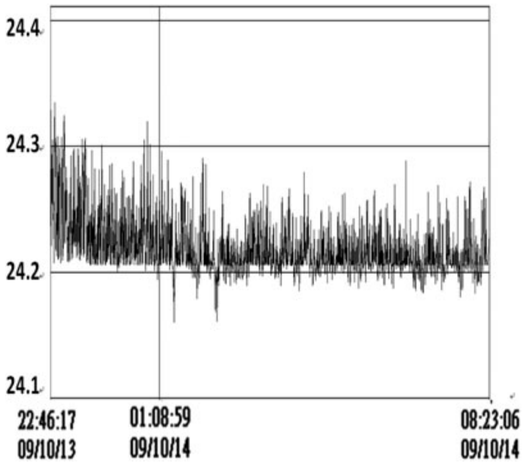

FIGURE 2. Air temperature history of the mock-up of 1/24 section.

larger than those on two sides connecting to adjacent 1/24 sections are shown on the virtual plane, especially on the upper area.

Figure 4 illustrates the simulated temperature contour in the storage ring tunnel. It shows that high-temperature areas are distributed on the booster magnets and the cable tray. Because the supplied air from air exits flows slightly in the $-X$ direction, temperature distribution on the lower area (small X coordinate area) is generally less than that on the upper area (larger X coordinate area).

Figure 5 shows the air temperature and velocity vector distributions on the virtual plane in Y–Z direction. White areas from left to right in the figure are cross-sections of two front ends, magnet, girder and the cable tray. Because air exits are distributed on the upper zone in the tunnel, as shown in the figure, clockwise

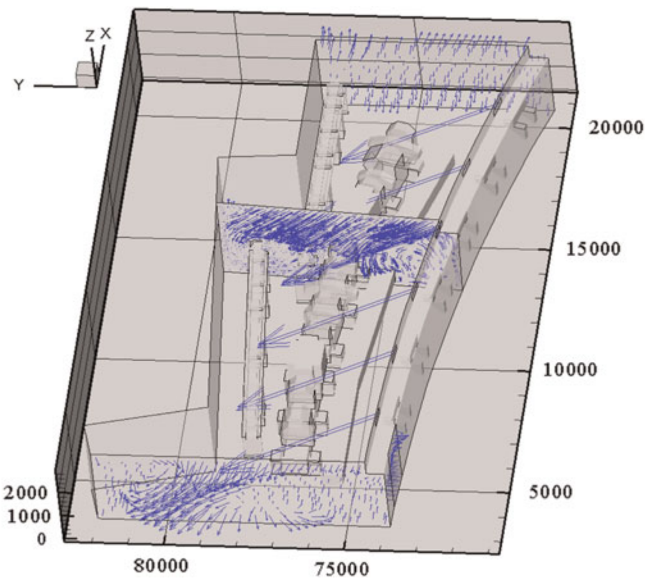

FIGURE 3. Model of 1/24 storage ring and simulated air velocity vectors.

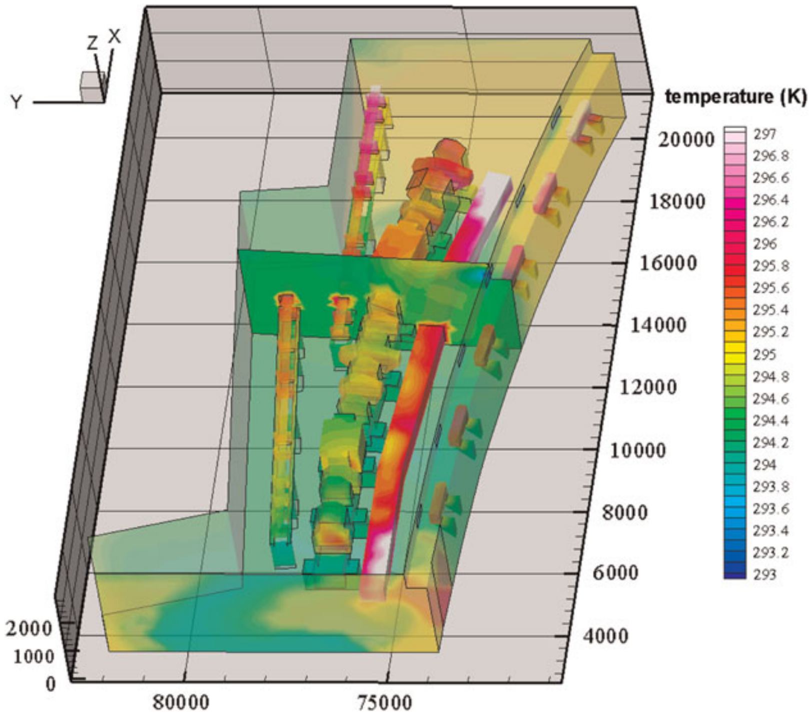

FIGURE 4. Simulated temperature distribution.

circulations around two front ends and on the right area are formed. Air velocities on the upper zone are also apparently larger. The temperature gradients near two front ends, magnet, girder and the cable tray are shown. And the effect of air circulation on the temperature gradient is clearly illustrated on areas below two front ends and upper right corner of the cable tray.

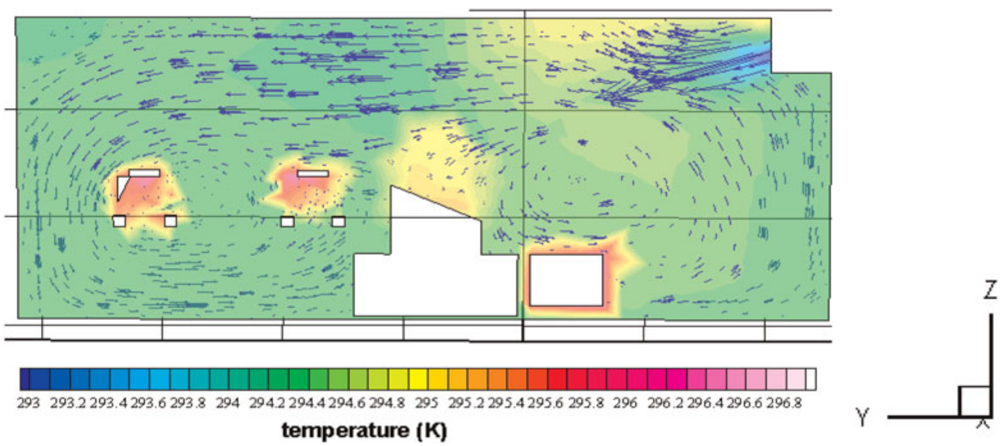

FIGURE 5. Air temperature distributions and velocity vectors on the virtual plane.

4. Conclusions

The mock-up of one-cell TPS tunnel experiment shows that we can control the air temperature variation within ±0.05°C without cooling load in the 10 h period. Numerical simulation of air temperature distributions and velocity vectors in the TPS tunnel will be an important reference for future improvement of the AC system.

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